# The effect of RBC stiffness on microhaemodynamics

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**Keywords:** Red blood cells, deformability, aggregation, apparent viscosity, micro particle image velocimetry

The multi-phase nature of blood poses many challenges in the understanding of microvascular flows. Red blood cells (RBCs) deliver oxygen and carbon dioxide to and from body tissues respectively. The ability of RBCs to deform is key to this function as it allows them to flow through microvessels with dimensions smaller than the cells. The morphology and mechanical properties of RBCs such as deformability and aggregability may change in disease (i.e. diabetes, malaria) or the presence of environmental stimuli such as drug therapeutics. These changes affect the rheology and hemodynamics in the microcirculation. Quantifying these changes is a very important step in understanding how erythrocyte properties impact on various pathologies.

In vivo animal studies have shown that reduced RBC deformability increases vascular resistance and the effect depends on the method and extent of RBC rigidification (Pantely et al. 1988; Chien 1987). Numerical studies by Fedosov et al. (2010) have demonstrated up to 50% increase in bulk viscosity with increasing levels of parasitemia i.e. percentage of malaria infected cells, in 20 μm vessel diameters and Ht = 0.45. Despite numerous studies on characterising RBC deformability there are no systematic in vitro studies on the effects of RBC deformability on velocity profiles and viscosity. RBC deformabilty is impaired to different extent in various conditions; hence it is important to systematically investigate the microscale behavior of RBC suspensions for varying levels of cell deformability and quantify the resulting haemodynamic changes.

In the present study we report preliminary experiments conducted with artificially stiffened human RBCs perfused through a straight 50μm square microchannel in order to assess the role of deformability on velocity characteristics and haematocrit distribution. Our aim is to quantify the extent RBC stifness alters haemodynamic and assessfinetune our measurement methodology before rolling it out to study occular pathologies (Agrawal et al. 2016).

RBCs were obtained by centrifuging human blood obtained from a healthy consenting donor, with ethical approval from the South East London NHS Research Ethics Committee (ref:10/H0804/21). RBCs were washed and re-suspended in PBS at two different haematocrit levels, 10% and 25% respectively. Various levels of membrane stiffening were introduced artificially by glutaraldehyde (GA) treatment to the samples (0.04% and 0.08% GA respectively). An unfixed sample was also prepared and used as control. Samples were perfused through the microchannels using an Elveflow microfluidic flow controller at flow rates ranging from 20 to 200 velocity per channel widths ($s^{-1}$). Quantitative imaging was performed using a Labview driven μPIV system described previously (Sherwood et al. 2014) using LED illumination and RBCs as tracers. The acquired images were processed using MATLAB and JPIV to obtain the velocity fields and haematocrit distributions.

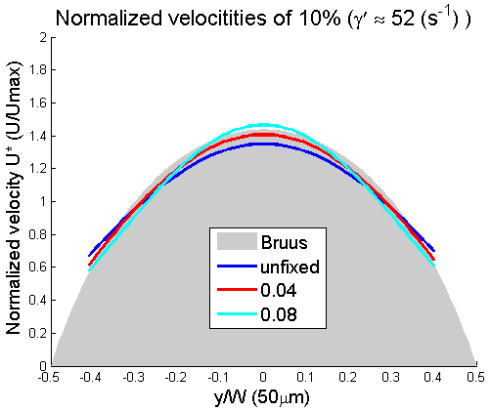


Figure 1: Velocity profiles normalised by the maximum velocity measured with healthy-unfixed, 0.04%, 0.08% GA treated samples at 52 $s^{-1}$ and Hct=10%. The grey area indicates the analytical velocity profile for square channel from Bruus.

Figure 1 shows typical velocity profiles normalised by the maximum velocity for samples with a haematocrit of 10%. It can be seen that RBC stiffening progressively reduces the bluntness of the velocity profiles which is well documented aspect of RBC flows. This is in contrast to the trends reported in the numerical studies of Fedosov (2010) and Zhang et al. (2009). It is well known that stiffening reduces the radial migration of RBCs -which is the cause of velocity blunting- and hence the hematocrit distribution, which may explain the observed velocity trends.

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